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## **DYNAMIC CONTENT CACHING FRAMEWORK**

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### **BACKGROUND OF THE INVENTION**

#### **Field of the Invention**

5           This invention relates to the client/server computing environment, and particularly to caching of content provided to users in a client/server computing environment.

#### **Description of the Related Art**

10           As more users begin to take advantage of businesses which use the Internet and the World Wide Web (the "web") to describe, market, sell, and deliver products and services, the performance of business web sites becomes an issue of greater importance.

15           Web documents, or web pages, are stored on numerous server computer systems ("servers") that are connected to the Internet. Each document on the web has a distinct universal resource locator (URL) which indicates where the document is located (e.g., the Internet domain name of the site on which the server is running, and the location on the server including file or directory specification) and how to access it (e.g., the protocol used when accessing the server containing the document). URLs can also include query strings so as to pass additional information to the Internet  
20           resource.

25           Many of the documents stored on web servers are written in one of several standard document description or markup languages such as Hypertext Markup Language (HTML) or Extensible Markup Language (XML). Using a markup language, a designer of web documents can associate hypertext links or annotations with specific words or phrases in a document and specify visual aspects and the content of a web page. The hypertext links identify the URLs of other web documents

or other parts of the same document providing information related to the words or phrases. Information within web documents and available for delivery in response to a user's request is generally referred to as "content" and can take a variety of forms including text, graphics, audio, video, and others.

5           A user accesses documents stored on the web using a web browser (a computer program designed to display markup language documents and communicate with web servers) running on a client computer system connected to the Internet. Typically, this is done by the user selecting a hypertext link (typically displayed by the web browser as a highlighted word or phrase) within a document being viewed  
10 with the web browser. The web browser then issues a hypertext transfer protocol (HTTP) request for the requested document to the web server identified by the requested document's URL. In response, the designated web server returns the requested document to the web browser, also using the HTTP.

          When the content of web pages is relatively static, *i.e.*, it does not change  
15 frequently, or require frequent updates, web site performance depends primarily upon the web site's ability to serve requested documents to users. Serving documents requires relatively little in the way of server computer system processing resources, and can be scaled to accommodate increasing numbers of users with relative ease. One technique to make delivery of static documents more efficient is to implement a  
20 web cache. A web cache can improve the response time to a particular user's request by storing a copy of the requested document on at least one alternate web site, one that is preferably closer to, or more accessible by, the user. Again, such systems work well when the documents are relatively static.

          However, as web site content becomes more sophisticated, it becomes more  
25 difficult to maintain high levels of performance. For example, if a user is configuring a product to be purchased from a business's web site, it is often desirable for the content of the web pages to be dynamic. If, on an opening web page, the user selects several product options, a subsequent web page can be very different, depending upon the options selected. To accommodate this kind of flexibility, many web pages (*e.g.*,  
30 the aforementioned subsequent web page) are only created by applications running on

or in conjunction with the web server computer system after a user has made a specific request. Such dynamic content production can be very computation intensive, and thus it can have a significant effect on server performance. Moreover, traditional web page caching systems are ineffective when the web page content is dynamic.

Accordingly, it is desirable to have a dynamic web content caching framework that allows for the caching and reuse of dynamically created documents in an efficient manner, thereby reducing the amount of computation required by web and/or application servers.

## 10 SUMMARY OF THE INVENTION

Sub A12 It has been discovered that a dynamic content caching framework that encodes dynamically created documents with a filename that is derived from the state information describing the contents of the document, advantageously allows for the dynamically created documents to be cached and reused, thereby reducing server computation, and allowing more users to utilize a particular web site. A file cache management system manages files that can be provided by a web server computer system to a client computer system. Parameters selected by a user viewing a web page define a presentation state that describes, and is used to produce, a subsequent web page. The presentation state is processed using a one-way hashing function to form a hash value, or signature, for that presentation state which is then used to identify the file in which presentation information for the presentation state is stored. When another user chooses the same presentation state, the existing file having presentation information can be identified quickly, an reused.

Sub A13 Accordingly, one aspect of the present invention provides a file cache management system for managing a plurality of files operable to be provided by an application running on a server computer system to at least one client computer system, wherein at least one of the plurality of files includes presentation information characterized by a first presentation state. The file cache management system includes a subsequent presentation state computation routine, and a presentation state signature computation routine. The subsequent presentation state computation routine

is operable to cause at least one subsequent presentation state to be computed based on the first presentation state. The presentation state signature computation routine is operable to determine a presentation state signature from at least one of the first presentation state and the at least one subsequent presentation state.

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In another aspect of the invention, a method of caching a file including presentation information characterized by a first state is taught. The file is operable to be provided by an application running on a server computer system to at least one client computer system. A file request is received including information based on the first state from the at least one client computer system. Whether the file exists in a cache is determined. The file is received and transmitted to the at least one client computer system when the file exists in the cache. Presentation information is computed based on the first state when the file does not exist in the cache. The computed presentation information is saved in a file in the cache and transmitted the file to the at least one client computer system.

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Another aspect of the present invention provides a file encoded in a computer readable medium as instructions executable on a processor, wherein the computer readable medium is one of a magnetic storage medium, an optical storage medium, and a communications medium conveying signals encoding the instructions. The file includes presentation information characterized by a presentation state, and a filename computed from the presentation state.

# BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may be better understood, and its numerous objects, features, and advantages made apparent to those skilled in the art by referencing the accompanying drawings.

25  
**Figure 1** illustrates a client/server computing environment utilizing a file cache management system.

**Figure 2** illustrates a web page displayed by browser software on a client computer system, and the various states associated with user selection combinations.

**Figure 3** is a flow chart describing a dynamic content caching framework.

### DETAILED DESCRIPTION

**Figure 1** illustrates a client/server computing environment for providing dynamically cached content to users via, for example, an interactive web site, and utilizing a file cache management system. Server **100** is typically a web server including the necessary hardware and software to serve HTML or XML documents, associated files, applications, and scripts to one or more client computers systems **160** when requested by a user of, or an autonomous program executing on, a client computer system. Client computer systems **160** typically utilize HTML or XML browsers to display the documents, and to generally interact with server **100**. As illustrated, server **100** and clients **160** are coupled to each other through a communications network **150**, such as the Internet. Server **100** and clients **160** can alternately be coupled to each other through point-to-point connections, or dedicated connections. Server **100** is typically an Intel Pentium-based or RISC based computer system equipped with one or more processors, memory, input/output interfaces, a network interface, secondary storage devices, and a user interface.

Server **100** includes three applications in addition to web serving functionality: cache manager **110**, content production **120**, and look-ahead manager **130**. Each of server **100**, cache manager **110**, content production **120**, and look-ahead manager **130**, are coupled to and communicate with file server **140**, which typically holds a plurality of files including presentation information files (e.g., HTML and/or XML documents) that are to be made available to users of client computer systems **160**. Although cache manager **110**, content production **120**, and look-ahead manager **130** are illustrated as part of (e.g., applications executing on) server **100**, each of the applications can reside on a separate application server, or various ones of the applications can be implemented on a single server. Moreover, although file server **140** is illustrated as a separate entity, it too can also be combined with one or more of server **100**, cache manager **110**, content production **120**, and look-ahead manager **130**.

**Figure 2** illustrates presentation information, or web page **210** displayed by browser software **200** executing on client computer system **160**. Web page **210** is

illustrative of a web page where a user can make a number of product-related configuration choices. Image **220** illustrates the product being configured, and can change depending on previous choices made by the user, as well as choices made by the user when interacting with web page **210**. Updating image **220** while the user selects various parameters on web page **210** can be accomplished via a script embedded in the web page, an applet downloaded with the web page, or via the markup language used to describe the page (*e.g.*, XML). Radio buttons **230** allow the user to select between category 1 and category 2, which can vary depending on the type of product being configured. Additionally various product options can be selected for a variety of product features. Pop-up menu **240** lists five user-selectable options **245** (option 5 being highlighted as if it has been selected) for a particular feature. Similarly, other selections can be made via pop-up menu **250**, clicking on images, or other graphical user interface (GUI) elements (*e.g.*, check boxes, slides, buttons, text entry boxes, etc., not shown), as is well known to those having ordinary skill in the art. Pointer **270** is a common GUI element used (under control of a pointing devices such as a mouse) to make selections. When the user is finished configuring the product as desired, he or she can cause the selections to be transmitted back to the server by actuating button **260**.

Given the configuration options made available to the user via web page **210**, two category options **230**, five feature 1 options **245**, and two feature 2 options (not shown), there are a total of 20 possible combinations of options. These different combinations will be used to configure the product, and thus are needed to determine the content of a subsequent web page (*e.g.*, an image of an automobile having the selected options, or a new series of configuration options that depend on the selections made in web page **210**). Each of those possible combinations is described by a state or presentation state, such as state 1 **280**, state 2 **281**, and state N **282**. Each state, in turn, is described by a computer readable representation, such as partial URL **290**. Partial URL **290** includes a filename **292** having a signature that is based on the presentation state, and thus the presentation information stored, in the file and representing the next document to be served when the user's selections in web page **210** resolve to that particular state. Partial URL **290** also includes an external representation of the state information **294**. State information is typically encoded in

a byte stream (understandable by, for example, cache manager **110**, content production **120**, and/or look-ahead manager **130**) and implemented as a URL query string. In this way, web page **210**, includes URLs (or partial URLs) for each next state. As will be seen below, these URLs are embedded in the presentation information that constitutes web page **210**.

As illustrated in **Figure 2**, the state information for each subsequent state from the state that defines web page **210** can include information about various selections made by the user (*e.g.*, category 1, Feature 1/Option 5, etc.). The state or presentation state information can also include additional information not directly related to the selections made by the user, or indeed not directly related to the presentation itself. For example, if web page **210** and the associated subsequent states were created based on one version of product configuration options, that version number can be included in the state information. In another embodiment, version information for all of the software and data used to produce a web page (*e.g.*, content production **120**, any markup language or style sheets, and a feature set) is encoded in the state information. Such version information allows server **100**, or associated applications to update or delete documents based on version information. If a user has an old URL that points to a web page that was created using an outdated version of the software and data, the user can be redirected to make a new configuration, and/or useful configuration information can be extracted from the old version and reused to create a new version of the web page. Those having ordinary skill in the art will readily recognize that a variety of different types of information and data can be included in a state or presentation state for the purposes of document encoding and dynamic content cache management.

**Figure 3** is a flow chart describing the dynamic content caching framework. The process begins at **300** where a web server (such as server **100**) receives a URL or partial URL for a selected subsequent state **290**. The server **100**, cache manager **110**, file server **140**, or some other process determines if the file described by the URL exists in the cache, as shown in **305**. The determination in **305** is preferably made by a combination of server **100** and another program. For example, when a user makes a file request by submitting a URL to a web server, an HTTP error 404 (file not found,

*i.e.*, a page fault) is typically returned to the user when the file cannot be found. Determination **305** can take advantage of this error reporting mechanism by hiding the error from the user, and using the occurrence of the error to cause the URL to be forwarded to the cache manager **110**. This is an easy and efficient mechanism to

5 determine when a cache miss has occurred.

If the file does exist in the cache, it is retrieved at **310**, based on the signature file name (*e.g.*, filename **292**). In an optional step **315**, look-ahead manager **130** is provided with information about the state that was requested, and/or information about the states subsequent to the state that was requested. As was shown in

10 conjunction with **Figure 2**, state information for subsequent states is encoded in the file describing the state being displayed (*e.g.*, web page **210**) and in states requested and retrieved.

Look-ahead manager **130** can use this information to determine if in fact files including the presentation information for the subsequent states exist, and if not, it can

15 initiate the content production for those subsequent states (which will then be stored in the filenames already specified) because that content is based on subsequent state information which is encoded in the URLs embedded in the retrieved file (*e.g.*, partial URL **290**, and state information **294**). This can enhance performance of the overall system because look-ahead manager **130** populates the cache with some or all of the

20 files necessary to display the next state selected by a user. Look-ahead manager **130** can continue this process further, by searching for and causing the computation of files based on the states subsequent to the subsequent states. The "depth" which look-ahead manager searches can be adjusted for optimal performance. This feature can also be used to initially populate a cache given the first possible state, and a

25 specification of how deep the look-ahead should be performed. Moreover, sophisticated look-ahead algorithms can be employed (*e.g.*, those used in chess programs, or those used for file access). In one example, look-ahead manager **130** can prune subsequent states, *i.e.*, suspend computation of presentations based on those states, when a user's subsequent state selection indicates the next path to be taken. In

30 general, look-ahead manager can optionally be used to enhance the performance of the dynamic content caching framework.



Once the requested file including presentation information is retrieved, as in **310**, the file is served to the requesting client computer, **355**.

When it is determined that the file described by the URL does not exist in the cache, operation proceeds to **320** where some or all of the information contained in the URL is forwarded to cache manager **110**. As before, the functions illustrated in **320** can be performed by the server **100** (e.g., an active server page (ASP) running on the web server, a Java server page (JSP) running on the server, a script, or an servlet), cache manager **110**, file server **140**, or some other process. In **325**, cache manager **110** determines if the state information **294** is included in the URL. In some situations, the amount of state information will be too voluminous to include as a query string in URL **290**. In those situations, a look-up table maintained by cache manager **110** and indexed by, for example, state signature **292**, will be consulted (**330**) to provide the necessary state information. The look-up table can also be used by look-ahead manager **130** to provided needed state information. In many situations, however, the state information will be encoded in the URL as illustrated in **Figure 2**, and the cache manager can extract that state information. Subsequent states are computed in **335** based on the extracted state information. This computation can be performed by cache manager **110**, or some other application. Next, signatures for each of the subsequent states are computed in **340**.

The state signatures, which are used for the filenames associated with presentation information representing the subsequent states, are typically computed using a hash function, and preferably a one-way hash function. Hash functions are used to convert an identifier, key, or other meaningful information (in this example the state information) into a value for the location of corresponding data (such as the computed HTML presentation corresponding to the state information). One-way hash functions, like regular hash functions, operate on an arbitrary-length piece of information (a "message") to return a fixed-length hash value. Unlike ordinary hash functions, one-way hash functions produce hash values that are essentially unique, that is there is only a very low probability that two different messages will have the same hash value. Consequently, one-way hash functions are useful in producing the essentially-unique signatures that can be used as filenames to identify web pages in

the cache. A variety of different one-way hash functions have been developed, each with varying degrees of computational complexity and security (*i.e.*, hash value uniqueness and reverse computability). Some one-way hash functions include Snefru, N-Hash, MD5, Secure Hash Algorithm (SHA), RIPE-MD, and HAVAL. These, and  
 5 other one-way hash functions are described in detail in *Applied Cryptography: Protocols, Algorithms and Source Code in C Management*, by Bruce Schneier, pp. 429-459, Wiley (1996), which is incorporated by reference herein, in its entirety.

Based on the state information extracted from the URL in **325**, or obtained by look-up in **330**, the presentation is computed in **345**. This process is typically  
 10 performed by content production **120**, and may include one or more interim steps, such as generating XML code and then using a style sheet (*e.g.*, based on the Extensible Stylesheet Language (XSL)) to produce HTML. Note that the XML and XSL code used to generate the presentation from a particular state can be specialized for that state, or for a class of states to which the state belongs. During this process,  
 15 URLs (including computed signatures and/or state information) representing the subsequent states are embedded in the presentation information. In step **350**, look-ahead manager **130** is optionally notified, and operates as described above. Finally, the requested file including presentation information is served to the requesting client computer in **355**, and the file including presentation information is saved to the cache  
 20 in **360**.

A variety of system refinements can be included to enhance operation of the overall client/server computing environment. For example, if two separate users were making selections that yielded the same state, and the cache did not include a  
 25 document for that state, two separate, and simultaneous attempts would be made to have the content generated, but both would require the same essentially-unique signature. In this instance, file server **140** could handle the filename contention by temporarily allowing the creation of two separate file, and then reconciling those files with the cache. Additionally, cache manager **110** can be part of a larger application, for example an server based application designed to provided configurable products as  
 30 part of the entire selling chain. File server **140** can include the cache itself, and be a shared resource among many different web servers, thereby allowing the various

cached states to be more efficiently utilized, particularly in an architecture where multiple web servers share a small number of (or one) file servers/page fault servers. Similarly, a dedicated look-ahead manager server can be implemented in conjunction with the file servers for more efficient operation.

- 5           In yet another example, it will be recognized that some web pages, *e.g.*, the first web page accessed as part of the process, might not include complete (or any) state information for subsequent states. In this case, the page should include some initial state information, so that the process outlines in **Figure 3** can operate properly.

- 10           The description of the invention set forth herein is illustrative and is not intended to limit the scope of the invention as set forth in the following claims. Variations and modifications of the embodiments disclosed herein may be made based on the description set forth herein, without departing from the scope and spirit of the invention as set forth in the following claims.